Annealing Effects on the High-Temperature Magnetic Properties of Ta/CoFeB/Ta Films

Hyejin Son,[1] **Byeongwoo Kang**,[1] **Ji-Hyeon Kwon**,[1] **and Byeong-Kwon Ju**[1]
[1] *Display and Nanosensor Laboratory, School of Electrical Engineering, Korea University, Seoul 02841, Republic of Korea*

Soft magnetic Cobalt–iron–boron (CoFeB) thin films have attracted significant interest for spintronic applications due to its high saturation magnetization and spin polarization. The structural and magnetic properties of CoFeB thin films are strongly influenced by sputtering power [1], post-annealing treatments [2], and variations in CoFeB layer thickness [3]. Spintronic devices operate at elevated temperatures, where thermal effects can alter magnetic damping. Since damping determines switching speed and power consumption, understanding its variation within the operating temperature range is crucial. Most experimental studies of CoFeB films have been limited to room-temperature measurements [4], which cannot provide a systematic understanding of their temperature-dependent damping.

In this study, we investigate the high-temperature magnetic properties of CoFeB thin films with different annealing conditions. Ta (5 nm)/$Co_{20}Fe_{60}B_{20}$ (35 nm)/Ta (3 nm) structures with different annealing conditions (as-deposited, 200 °C, 300 °C, and 400 °C) were measured by ferromagnetic resonance (FMR) spectroscopy at temperatures ranging from 30-160°C to extract the linewidth and resonance magnetic field for dynamic property analysis (Fig. 1). The raw FMR spectra of the 300 °C annealed sample measured at 160 °C showed a monotonic increase in both the resonance field and linewidth with increasing frequency (Fig. 1(a)). The normalized FMR spectra at a fixed frequency of 14 GHz exhibited a gradual increase in both parameters with temperature (Fig. 1(b)). Analysis of the linewidth further showed that the Gilbert damping constant α decreases in the annealed samples compared with the as-deposited film (Fig. 1(c)). The effects of annealing on the high-temperature magnetic response of symmetric Ta/CoFeB/Ta multilayers will be further discussed.

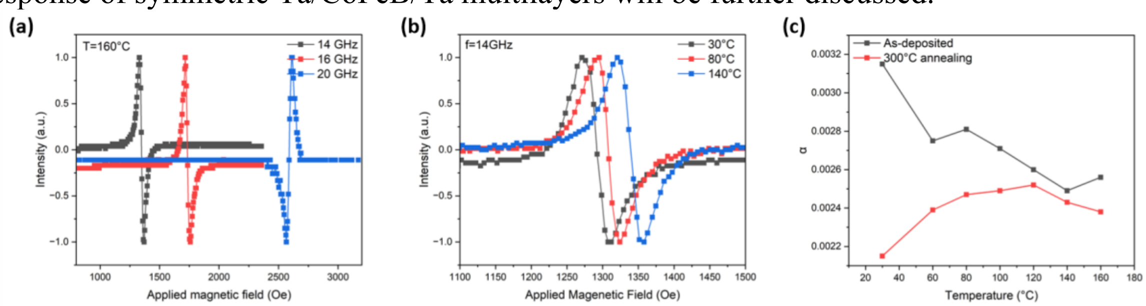

Figure 1. FMR absorption spectra of the 300 °C annealed sample measured (a) at 160 °C with different frequencies and (b) at a fixed frequency of 14 GHz with different temperatures. (c) Gilbert damping constant of as-deposited sample and the 300 °C annealed sample as a function of temperature.

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[2] M. Arif, X. Zhang, M. Amir, et al., J Mater Sci: Mater Electron 34, 574 (2023).
[3] G. Lu, X. Huang, S. Fan, W. Ling, M. Liu, J. Li, L. Jin, and L. Pan, J. Alloys Compd. 753, 475 (2018).
[4] S. Pan, S. Choudhury, J. Sinha, A. Barman, J. Magn. Magn. Mater. 502, 166545 (2020).

Supplementary Information:

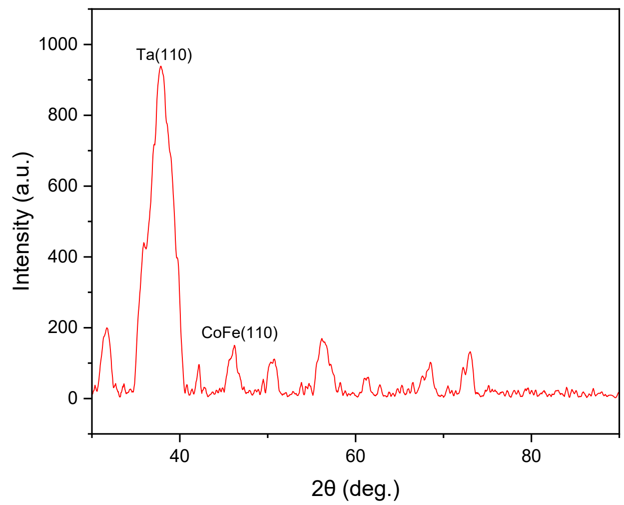

Figure 2. X-ray diffraction (XRD) pattern of the 300 °C annealed sample, showing diffraction peaks at 38.4° and 44.7° corresponding to the (110) planes of bcc α-Ta and bcc CoFe. These results indicate crystallization of the initially amorphous CoFeB into the CoFe phase.